

Research on the Impact of Digital Logistics Capability on Sustainable Operation Performance of E-commerce Logistics Enterprises

Kaiwen Guo *

School of Economics and Management, Southwest Petroleum University, Chengdu 610500, China

* Corresponding author: (Email: 2870187387@qq.com)

Abstract: Global logistics industries are undergoing widespread digital transformation, which has become a decisive factor promoting sustainable operational improvement for e-commerce logistics service providers. Conventional logistics operation modes are frequently criticized for high operational costs, inefficient resource allocation and insufficient low-carbon operational capacity, making it difficult to accommodate the personalized and high-frequency logistics demands generated by booming online retail markets. Based on valid data collected from 312 domestic e-commerce logistics firms, this study establishes an empirical framework to explore how multi-dimensional digital logistics capabilities affect corporate sustainable operational performance. Four core capability dimensions are adopted as independent variables, including data acquisition and analysis capability, intelligent scheduling optimization capability, cross-enterprise resource collaboration capability and digital service iteration capability. Sustainable operational performance is comprehensively measured from economic, ecological and service quality perspectives. Empirical results derived from reliability verification, correlation analysis and multiple regression estimation demonstrate that all digital capability dimensions positively and significantly enhance corporate sustainable performance. Among these indicators, intelligent scheduling capability presents the strongest predictive power with a regression coefficient of 413, followed by resource collaboration and data analysis capabilities. Further heterogeneity analysis reveals that medium-sized logistics enterprises benefit most from digital upgrading, while micro and large-scale firms display relatively weaker performance improvement effects. This research clarifies the internal driving mechanism of digital empowerment in sustainable logistics operations and provides practical optimization suggestions for enterprises intending to promote digital transformation and long-term high-quality development.

Keywords: Digital Logistics Capability; E-commerce Logistics; Sustainable Operational Performance; Corporate Management; Empirical Study.

1. Introduction

Driven by global digital economic expansion and continuous e-commerce market growth, traditional logistics industries are experiencing profound structural upgrading and operational reform. Modern consumer online shopping behavior features fragmented order distribution, diversified commodity types and rapid order turnover, which imposes higher requirements on logistics response speed, cost control level and environmental protection performance. Traditional logistics operation modes that rely heavily on manual scheduling and empirical management often lead to redundant transportation routes, excessive energy consumption and unstable service quality, which hinder the sustainable development of e-commerce logistics enterprises.

Digital technology empowerment effectively solves many operational bottlenecks in traditional logistics scenarios. The integration of big data computing, cloud platform management and intelligent scheduling algorithms enables logistics enterprises to realize refined management of warehousing, transportation and terminal distribution links.

Existing academic outcomes have proven that digital transformation can effectively reduce operational costs and improve logistics efficiency, yet most previous studies only focus on single-dimensional economic benefits, ignoring the comprehensive improvement of environmental performance and customer service quality. In addition, the differentiated influence of various digital capability dimensions on enterprise sustainable development remains insufficiently discussed, resulting in limited practical guidance for enterprises of different scales. Based on the above research deficiencies, this paper conducts quantitative empirical analysis to fill the research gap in multi-dimensional digital logistics sustainable development.

To systematically address the research gap, this study constructs a conceptual framework that links four distinct digital capability dimensions to three pillars of sustainable operational performance. Figure 1 illustrates the hypothesized relationships among the constructs, where each digital capability is expected to positively influence economic, ecological and service-related performance outcomes. The framework also incorporates enterprise size as a moderating factor for heterogeneity analysis.



Figure 1. Conceptual Research Framework

The remainder of this paper is organized as follows. Section 2 reviews relevant literature and develops research hypotheses. Section 3 describes the research design, including data collection, variable measurement and analytical procedures. Section 4 presents empirical results, including reliability tests, correlation analysis, regression estimates and heterogeneity tests. Section 5 provides discussion of the findings and their managerial implications. Section 6 concludes with limitations and future research directions.

2. Literature Review and Research Hypothesis

2.1. Digital Logistics Capability

Digital logistics capability refers to the comprehensive operational competitiveness formed by enterprises through digital technology penetration and business process reconstruction. Different from traditional logistics capability focusing on hardware facilities and labor resources, digital logistics capability emphasizes data-driven decision-making and intelligent process optimization. It can be divided into four major dimensions. Data perception and analysis capability reflects enterprises' ability to capture real-time market demand, monitor operational data and identify operational risks through digital platforms. Intelligent scheduling capability represents the optimization of distribution paths, inventory allocation and human resource arrangement supported by intelligent algorithms. Resource collaboration capability realizes information interconnection and business coordination among suppliers, warehousing centers and terminal distribution teams. Digital service capability focuses on online order tracking, intelligent customer response and personalized service optimization.

2.2. Sustainable Operational Performance of Logistics Enterprises

Sustainable operational performance is a comprehensive evaluation indicator covering economic benefits, ecological environmental protection and social service value. In the e-commerce logistics industry, economic performance is mainly reflected in operational cost control efficiency and profit stability. Ecological performance focuses on carbon emission reduction, packaging resource recycling and energy consumption optimization in logistics activities. Service performance evaluates order completion rate, distribution timeliness and customer satisfaction degree. The three dimensions jointly reflect the long-term development potential and comprehensive market competitiveness of logistics enterprises.

2.3. Research Hypothesis

Digital technology application can effectively optimize

logistics operation processes, reduce invalid resource consumption and improve overall service quality. The improvement of digital logistics capability helps enterprises achieve cost reduction, low-carbon operation and service upgrading simultaneously. Accordingly, this study proposes the core hypothesis that each dimension of digital logistics capability exerts a significant positive influence on the sustainable operational performance of e-commerce logistics enterprises, and obvious heterogeneity exists in the influence intensity of different capability indicators.

Specifically, we hypothesize:

H1: Data acquisition and analysis capability positively affects sustainable operational performance.

H2: Intelligent scheduling optimization capability positively affects sustainable operational performance.

H3: Cross-enterprise resource collaboration capability positively affects sustainable operational performance.

H4: Digital service iteration capability positively affects sustainable operational performance.

H5: The influence strength of the four capabilities varies across enterprise size groups.

3. Research Design and Empirical Analysis

3.1. Data Source and Sample Structure

The empirical data of this study is obtained through field questionnaire investigation targeting domestic e-commerce logistics enterprises. The research period spans from March to April 2022. Questionnaires are distributed to enterprise operation managers, logistics supervisors and technical staff with practical working experience. A total of 350 questionnaires are issued, and 312 valid samples are finally screened out after eliminating invalid data with regular answers, missing items and logical contradictions, achieving an effective recovery rate of 81%. In terms of sample distribution, medium-sized enterprises account for the largest proportion of 57%, small enterprises account for 15%, and large-scale logistics enterprises account for 28%. The sample structure conforms to the current development characteristics of China's e-commerce logistics industry, ensuring the representativeness and scientificity of empirical conclusions.

Table 1 presents the demographic characteristics of the sample, including enterprise size, years of operation, ownership type and regional distribution. The majority of firms (62%) have been in operation for more than 5 years, indicating a mature industry base. Geographically, samples are drawn from eastern, central and western regions, with eastern regions accounting for 55%, reflecting the higher concentration of e-commerce logistics activities in coastal areas.

Table 1. Sample Descriptive Statistics

Characteristic	Category	Frequency	Percentage
Enterprise Size	Micro & Small	47	15.10%
	Medium	178	57.00%
	Large	87	27.90%
Years in Operation	<3 years	48	15.40%
	3-5 years	70	22.40%
	>5 years	194	62.20%
Region	Eastern	172	55.10%
	Central	89	28.50%
	Western	51	16.40%

3.2. Variable Measurement Standard

All latent variables involved in this study are measured using a mature five-point Likert scale. The scoring range is set from one to five points, representing strongly disagree to strongly agree respectively. All measurement items are revised and optimized on the basis of classic domestic and foreign scales to adapt to the actual development situation of China's e-commerce logistics industry. The independent variable includes four sub-dimensions of digital logistics capability (each measured by 4-5 items), while the dependent variable covers economic, green and service dimensions of sustainable operational performance (each measured by 3-4 items). Control variables include firm age, firm size (measured by number of employees and annual revenue), and regional dummies.

Table 2. Pearson Correlation Matrix

Variables	1	2	3	4	5
1. Data Analysis Cap.	1				
2. Intelligent Sched.	0.412**	1			
3. Resource Collab.	0.387**	0.455**	1		
4. Digital Service Cap.	0.356**	0.402**	0.378**	1	
5. Sustainable Perf.	0.421**	0.498**	0.462**	0.351**	1

*Note: * $p < 0.01$ (two-tailed).

Multiple linear regression analysis is further conducted to test the specific influence relationship. The adjusted R^2 of the whole model is 0.472, indicating that the selected independent variables can explain 47.2% of the variance of enterprise sustainable performance, with ideal model fitting effect. The regression results (see Table 3) show that intelligent

3.3. Reliability and Validity Test

Reliability test results indicate that the overall Cronbach's α value of the scale reaches 0.896, and the α values of all sub-dimensional variables exceed 0.82, which proves that the questionnaire data has excellent internal consistency and statistical reliability. Confirmatory factor analysis results show that the factor loading of all measurement items ranges from 0.71 to 0.87. The average variance extraction (AVE) value of each variable is higher than 0.52, and the composite reliability (CR) coefficient is greater than 0.83, fully verifying the good convergent validity and reasonable variable structural design of the research scale. Discriminant validity is also confirmed as the square root of AVE for each construct exceeds its correlations with other constructs.

3.4. Correlation and Regression Analysis

Pearson correlation analysis results (see Table 2) demonstrate that all sub-dimensions of digital logistics capability show significant positive correlation with sustainable operational performance at the 1% statistical level, which initially supports the rationality of the research hypothesis. The correlation coefficients range from 0.351 to 0.498, indicating moderate to strong associations. Among the independent variables, intelligent scheduling capability exhibits the highest correlation with sustainable performance ($r = 0.498$, $p < 0.01$), followed by resource collaboration ($r = 0.462$).

scheduling capability has the strongest promotional effect with a coefficient of 0.413 ($p < 0.001$). The coefficients of resource collaboration capability, data analysis capability and digital service capability are 0.326 ($p < 0.01$), 0.278 ($p < 0.01$) and 0.226 ($p < 0.05$) respectively. All variance inflation factor (VIF) values are below 2.5, confirming the absence of multicollinearity.

Table 3. Multiple Regression Results

Independent Variable	Unstandardized β	Standardized β	t-value	Sig.
(Constant)	1.254	—	3.892	0
Data Analysis Cap.	0.278	0.241	3.456	0.001
Intelligent Sched. Cap.	0.413	0.367	5.672	0
Resource Collab. Cap.	0.326	0.289	4.213	0.002
Digital Service Cap.	0.226	0.198	2.891	0.018
Firm Age (control)	0.052	0.067	1.234	0.218
Firm Size (control)	0.089	0.102	1.876	0.062

$R^2 = 0.485$, Adjusted $R^2 = 0.472$, $F = 28.347$ ($p < 0.001$)

3.5. Heterogeneity Test

In order to explore the differentiated influence of digital capability on enterprises of different scales, this study conducts grouped regression analysis (see Table 4). The

empirical results show that medium-sized logistics enterprises obtain the most significant performance improvement from digital transformation, with an overall influence coefficient (standardized β) of 0.531. Large enterprises have a relatively stable promotion effect with a coefficient of 0.381, while micro and small enterprises show

the weakest transformation benefit with a coefficient of 0.241. The results reflect that medium-sized enterprises are in the critical stage of operational upgrading and have the highest marginal return on digital investment. For micro and small firms, resource and financial constraints may limit the effective absorption of digital technologies, while large firms may already operate at high efficiency levels, leaving less room for marginal gains.

Table 4. Grouped Regression Results by Enterprise Size

Enterprise Size	N	Standardized β (overall)	Adjusted R^2	F-value
Micro & Small	47	0.241*	0.312	6.789
Medium	178	0.531***	0.523	34.562
Large	87	0.381**	0.445	15.234

*Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4. Discussion

The empirical findings fully confirm that digital logistics capability is a core driving factor for the sustainable development of e-commerce logistics enterprises. Intelligent scheduling capability plays a leading role in promoting sustainable performance because it effectively solves practical pain points such as unreasonable distribution paths and repeated transportation in e-commerce logistics scenarios, thereby reducing energy consumption and operational costs while improving distribution efficiency. Cross-enterprise resource collaboration and data analysis capability realize precise matching of market supply and demand and optimal allocation of logistics resources, which lay a solid foundation for stable enterprise operation. Digital service capability helps enterprises optimize customer experience and enhance long-term market competitiveness.

Interestingly, the heterogeneity results reveal a non-linear relationship between enterprise size and transformation benefits. Medium-sized firms achieve the highest returns, possibly because they possess sufficient organizational flexibility and resource slack to experiment with new digital tools, yet they are not burdened by the bureaucratic inertia often found in large corporations. Small enterprises, despite their agility, lack the financial and technical expertise to fully deploy advanced digital systems, resulting in lower performance improvements. These findings echo the "digital divide" literature and suggest that policymakers and industry associations should provide targeted support for small logistics firms, such as subsidized cloud-based logistics platforms and training programs.

Furthermore, our study contributes to theory by integrating four previously scattered capability dimensions into a unified empirical model. The significant coefficients for all four dimensions validate the multidimensional nature of digital logistics capability, implying that a piecemeal approach to digital transformation (e.g., focusing only on data analytics without improving scheduling) may yield suboptimal outcomes. Managers should therefore adopt a balanced portfolio of digital investments, prioritizing intelligent scheduling and resource collaboration, while not neglecting data and service capabilities.

In terms of practical management implications, e-

commerce logistics enterprises should prioritize the construction of intelligent scheduling systems and accelerate the digital upgrading of core operational links. Medium-sized enterprises should take digital transformation as the core development strategy to break through operational bottlenecks, while small and micro enterprises should adopt progressive lightweight digital construction according to their own financial and operational conditions to avoid excessive investment pressure and resource waste. For large enterprises, continuous optimization and integration of existing digital systems, along with fostering a data-driven culture, can further sustain their competitive advantage.

5. Conclusion

Taking 312 e-commerce logistics enterprises as research samples, this paper systematically explores the influence mechanism of multi-dimensional digital logistics capability on corporate sustainable operational performance. The research results verify that data analysis capability, intelligent scheduling capability, resource collaboration capability and digital service capability can significantly promote the simultaneous improvement of enterprise economic benefits, green operation level and service quality, and the influence effect presents obvious enterprise scale heterogeneity. This study enriches the empirical research system of digital logistics and sustainable operation, and provides reliable theoretical support and practical reference for the digital transformation and high-quality development of e-commerce logistics enterprises.

Despite these contributions, several limitations should be acknowledged. First, the cross-sectional design precludes causal inferences; future research could adopt longitudinal or quasi-experimental approaches to establish causality. Second, the data are self-reported, which may introduce common method bias, although the Harman's single-factor test indicated that no single factor accounted for the majority of variance. Third, the study focuses exclusively on Chinese e-commerce logistics firms, so generalizability to other countries or industries requires caution. Future studies could compare digital transformation effects across different cultural and regulatory contexts. Additionally, exploring the mediating role of organizational learning or innovation culture could deepen our understanding of the underlying mechanisms.

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